Mode 12 Test Plan

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INTRODUCTION

RD Instruments (RDI) has introduced a new high sample rate water mode (Mode 12) that promises to expand the capability of the Rio Grande instruments in both shallow and deep water. Mode 12 is based primarily on a mode 1 ping but the way the ping is processed and averaged is different.

During a mode 1 ping the following steps occur: 1) the sensors (pitch, roll, and heading) are read, 2) the acoustic pulse is sent and returns, 3) the pulse is processed, 4) the velocities are transformed to instrument, ship, or earth coordinate systems, and 5) the data are communicated to the laptop computer. A mode 1 multi-ping ensemble repeats steps 1-4 multiple times then averages all of the pings prior to step 5. Thus a mode 1 multi-ping ensemble saves the overhead of communicating the data to the laptop with each ping; however, the price to be paid is that ambiguity errors in individual pings are smeared (hidden) in the averaging process.

Water mode 12 is much like a mode 1 multi-ping ensemble except the sensors are only sampled one time a the beginning of a mode 12 ping and the subpings are averaged in complex space before transforming the data. The result of this is that mode 12 can collect and average more pings than a multi-ping mode 1 ensemble in a given amount of time and by averaging prior to transformation, smearing (hiding) ambiguity errors is eliminated. The price to be paid for this approach is that the sensors are only sampled one time at the beginning of the sequence. Therefore, if too many subpings are averaged and the ensemble takes too long the attitude of the boat may change sufficiently to corrupt the data. However, mode 12 collects more samples (RDI claims it can sample a 20 Hz), reducing the standard deviation of the velocity measurements, which makes the use of small bins more practical.

Preliminary testing of this mode revealed no obvious problems but many different options and configurations need to be tested and compared with a comparison measurement to develop defensible configurations guidelines and application limits. This document was prepared to define the tests that need to be completed and provide guidance to anyone wishing to complete some of these tests and provide the results to David S. Mueller for analysis and inclusion in a USGS document on the evaluation of water mode 12.

COMPARISON MEASUREMENTS

Defining absolute truth in the field is difficult, if not impossible. However, our standard over the years has been a Price AA or Pygmy meter measurement made in accordance with the standards defined in Water-Supply Paper 2175. Due to unsteady flow a direct comparison may not be possible so we will define four types of comparisons that could be made in descending order of confidence. You must provide all the documentation to support the comparison with your submission of comparison data. All data must be collected using standard procedures defined in the attached document.

1. **Comparison to simultaneous cup meter measurement.** The most defensible comparison is made when the discharge is measured simultaneously with both a cup meter and an ADCP. To minimize the effects of unsteady flow the cup meter and ADCP measurements should start and stop at the same time. This may mean that many more than 4 ADCP transects are collected. The comparison discharge should be based on the average of all ADCP transects collected during the cup meter measurement.

2. **Comparison to a rating curve.** At locations where it can be demonstrated that the rating curve is accurate and does not change significantly, measurements can be compared to the rated discharge. For this situation, it is recommended that the rating curve be verified twice on the day of the comparison, once at the beginning of the comparison period and once at the end. Verification can be by a standard cup meter measurement or by an ADCP using water modes 1, 5, or 11 as determined by site conditions. Individual comparison measurements can contain as few as four transects that fall within 5 percent of the mean of those 4 transects. However, for the mode 12 measurements a minimum of 8 transects are preferred. By collecting more transects, statistics on the variability of a particular configuration can be computed more accurately.

3. **Comparison to other simultaneous ADCP measurements.** Where two ADCP's can be used concurrently (usually a 600 kHz and a 1200 kHz) one of the instruments can be operated in water mode 1, 5, or 11 and the other in various configurations of water mode 12. Positional and other sources bias of the instruments should be evaluated to ensure that any differences in discharge are attributed to the difference in water mode configurations. Individual comparison measurements can contain as few as four transects that fall within 5 percent of the mean of those 4 transects. However, for the water mode 12 measurements 8 transects are preferred. By collecting more transects, statistics on the variability of a particular configuration can be computed more accurately.

4. **Comparison of sequential ADCP measurements.** Where flow is steady, it is not practical to measure the discharge with conventional methods, and the rating curve is unreliable sequential ADCP measurements can be used for comparison. This involves making a water mode 1, 5, or 11 measurement using standard procedures and then making water mode 12 measurements. In this comparison we are assuming that the flow is not changing between the measurements, which is seldom absolutely true but may be an acceptable assumption at some sites. The mode 1, 5, or 11 measurements can contain as few as four transects that fall within 5 percent of the mean of those 4 transects. However, for the water mode 12

measurements 8 transects are preferred. By collecting more transects, statistics on the variability of a particular configuration can be computed more accurately.

TEST CONFIGURATIONS

Mode 12 can be configured with a wide range of bin sizes, ambiguity velocities, and number of subpings resulting in a large number of combinations that could be tested. To focus our efforts on defining the limits and capabilities of mode 12, the following test combinations are recommended for testing in order of priority:

Table For 1200 kHz Rio Grande

Test	Bin Size	Number Subpings	WV	Comments (user commands)
1	10	12	340	Config wizard 12SB
2	25	12	175	Config wizard 12RB (WV175)
3	10	12	175	Config wizard 12SB (WV175)
4	5	12	175	Config wizard 12SB (WV175; WN?; WK5)
5	5	12	480	Config wizard 12SB (WN?; WK5; WV480)
6	2	12	480	Config wizard 12SB (WN?; WV480; WK2)
7	2	6	480	Config wizard 12SB (WN?; WV480; WO6,4; WK2)
8	25	4	175	Config wizard 12RB (WV175, WO4,4)
9	25	8	175	Config wizard 12RB (WV175, WO8,4)
10	1	12	480	Config wizard 12SB (WN?; WV480; WK1)
11	1	6	480	Config wizard 12SB (WN?; WV480; WK1; WO6,4)
12	10	36	175	Config wizard 12SB (WV175; WO36,4)

Table for 600 kHz Rio Grande

Test	Bin Size	Number Subpings	WV	Comments (user commands)
1	25	12	340	Config wizard 12SB
2	50	12	175	Config wizard 12RB (WV175)
3	25	12	175	Config wizard 12SB (WV175)
4	10	12	175	Config wizard 12SB (WV175; WN?; WK10)
5	10	12	480	Config wizard 12SB (WN?; WK10; WV480)
6	5	12	480	Config wizard 12SB (WN?; WV480; WK5)
7	5	6	480	Config wizard 12SB (WN?; WV480; WO6,5; WK5)
8	50	4	175	Config wizard 12RB (WV175, WO4,5)
9	50	8	175	Config wizard 12RB (WV175, WO8,5)
10	2	12	480	Config wizard 12SB (WN?; WV480; WK2)
11	2	6	480	Config wizard 12SB (WN?; WV480; WK2; WO6,5)
12	25	36	175	Config wizard 12SB (WV175; WO36,5)

> Note: WN? means the user will have to recompute the number of depth cells from what the wizard computed due to a change in depth cell size. Maximum WN is 255.

These 12 tests will allow evaluation of the bin size and of the importance of WV and the number of subpings. It is recommended that all configurations start with the configuration wizard and then add the additional user commands as necessary. Site conditions will dictate which modes and WV's are appropriate.

The priorities were assigned based on an estimate of frequency of current and future applications and the need to define some of the limits particularly for small bins in shallow water.

TIME BETWEEN PINGS

The configuration wizard uses a default time between pings (second variable in the WO command) of 40 ms for a 1,200 kHz Rio Grande and 50 ms for a 600 kHz Rio Grande. It is recommended, but not required, that the actual minimum time between pings be measured on site (see Appendix A). If you are using these modes in water deeper than about 8 m, the ping to ping interference test in Appendix A is highly recommended as the default value may be too low. It is preferred that you collect data both with the default time between pings and the value measured on site. The WO command must be modified to use measured values.

SITE CONDITIONS

The site conditions should be completely documented, for completeness and to facilitate use of these data by others. Video or digital pictures are encouraged. The flow, bed conditions, weather, mounts, boats, and other equipment should be documented. If necessary use a tape recorder to ensure detailed notes and then transcribe them back in the office.

SUBMITTING DATA

Data submitted for the comparisons described herein should be sent via FedEx or a note to dmueller@usgs.gov with information as where the data can be downloaded. This submission should include all raw data, supporting information used to make the comparison, documentation of any deviation from standard procedures, and documentation of site conditions. Please do not email large data sets without prior notification and approval.

FedEx address:

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APPENDIX A: PING-TO-PING INTERFERENCE

It is usually desirable to have as high a ping rate as possible. Higher ping rates usually reduce the variance of the measurement of the water velocity. A higher ping rate also gets the water- and bottom-track pings closer together in time. This has the effect of reducing the noise on the calculation of the water velocity. The limitation on ping rate may be set by the user set-up and the ADCP's ability to process data. For example a long profile with a large number of Bins may be the limiting factor on the ping rate. Quite often, however, this is not the controlling factor. In this case, Ping-to-Ping interference becomes the controlling factor. Ping-to-Ping interference is a term for the energy from a previous ping interfering with the reception of the current ping. A ping is initiated by a transmitted pulse. This pulse propagates through the water column and is reflected back (backscattered) by scatterers in the water column. It is also reflected back by the bottom, structures and vessels in the vicinity of the ADCP, and perhaps sides of a river. These reflections can be enormously stronger than that from the water column. It is not unusual for the signal that travels from the ADCP to the bottom, back to the surface, back to the bottom and back again to the ADCP to be larger than the signal from the water column. This phenomenon is called "second bounce". In fact, many "bounces" may be required for the signal level to "die down" enough so that it doesn't interfere with the current ping. Similar interference can come from other reflectors in the vicinity. The important point is that one cannot start a new ping until this interference from the previous ping has diminished to the point where it won't interfere with this new ping.

It is impossible to give hard and fast guidelines for how long a time to wait because of the large variations in bottom type, what if anything, structures might do and the variation in absorption losses. Additionally, there may be scatterers in the vicinity of the instrument such as weeds, riverbanks, channel walls, etc. The scattering characteristics of bottoms can vary by more than 30dB and the absorption losses between fresh water and salt water vary by another 10dB. Additionally, the water backscattering can vary by another ±20dB. Boundaries can have a wide range of scattering values.

To achieve high ping rates (using WaterMode12, for example), you can evaluate the environment using the following test:

Use WinRiver or other suitable software to send the following commands:

CR1
BP0
WP1
WS100
WN128
TE00000000
TP000000

Set up WinRiver to display the Intensity profile. Monitor the Intensity and Correlation as a function of range. One will normally see a falling Intensity level and Correlation level as the transmit pulse propagates down through the water column. Then, as the pulse strikes the bottom, one will see an increase in each. After the pulse passes through the bottom, one will see both values fall again. At very far ranges, the Intensity should fall to the system noise level (~40 counts). At any point in the profile one might see increases due to other scatterers such as boats, structures, etc. One might also see multiple bounces off of the bottom. The purpose of this test is to determine at what range the Intensity and Correlations reach the system noise level and stay there for the rest of the profile. To determine the minimum time between pings we multiply that range by 1.5ms/m to obtain the minimum time between pings that is safe.

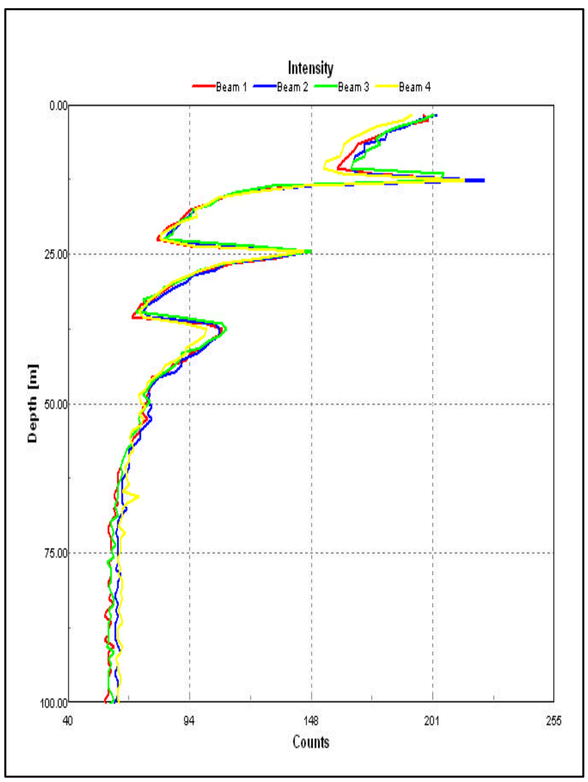
At an absolute minimum, we recommend sufficient time between pings for the previous pulse to travel 3 round trips to the bottom. In other words, a minimum of 3 times the distance to the bottom, times the travel time in meters/second (~1.5ms/meter) should be allowed. A small amount of time should be added to this to insure that the pulse has gone past the instrument on the third bounce. This applies when the distance to the bottom is at or near the maximum bottom tracking range of the instrument. For smaller distances to the bottom, the loss caused by absorption decreases, and we recommend you require more bounces before the next ping is initiated.

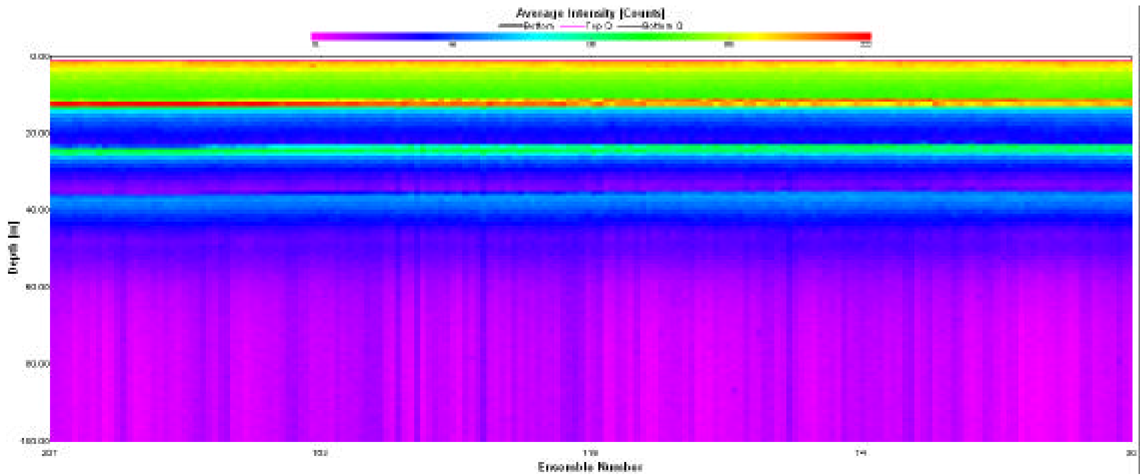
NOTE: This test should be conducted at different locations on your planned transect. Changing depths and paths to obstacles may be changing. The longest ping time obtained should then be used.

NOTE: If the signal doesn't die down enough in 255 meters, then increase the Bin size (WS command). Conversely, if it dies down quickly and more range resolution is desired then either decrease the Bin size or the number of Bins. The only requirement is that the profiling range be long enough for the Intensity to die down to the system noise level (~40 counts).

EXAMPLE

You can determine the noise level using the profile plot or the contour plot. Here the noise level (approximately 60 counts) is reached at about 60 m.





71 m is where you see the contours go to noise level. Note the color scale can be important if you use the contour plot.

Standard Procedures for Collection of Discharge Data

- Follow all OSW recommended procedures for making a discharge measurement except as noted in test plan.
- Use standard USGS Acoustic Profiler Discharge Measurement Notes (Form 9-275-I), if possible.
- Use WinRiver 10.06
- If possible, collect 12 transects to get a better estimate of the instrument / river variability and to allow evaluation of 2, 4, 6, and 8 transect averages.
- Record air temperature and water temperature
- Document speed and direction of wind.
- Calibrate compasses prior to data collection using CompCal or AF and AX.
- Run RGTest prior to measurements
- Configure ADCP using the ConfigWizard and document any user commands that may be recommended by the test procedure.
- Set time on PC and ADCP.
- Accurately measure draft, particularly on shallow streams. Be sure to compensate for pitch or roll of the boat during this measurement. If a pressure sensor is used, be sure and zero it and check for reasonableness of the draft measurement.
- Locate a section with uniform flow, if possible.
- Document any observed reverse flow at the edges.
- Set starting and stopping edge to allow two good depth cells at each edge. If this is not possible, document why.
- Collect at least 10 ensembles in a stationary position at the beginning and end of each transect.
- Use buoys to ensure consistent starting and stopping points, if possible. Measure distance to shore from each buoy.
- Always *measure* distance to shore for each transect, if buoys are not used.
- Maintain a boat speed equal to or less than the water speed, if at all practical. Document reasons for deviation.
- When possible, collect at least one and preferably 2 cup meter measurements. Where there is changing flow conditions, it will be important to identify which transects were collected during the cup meter measurement.